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SEVERAL CRITERIA FOR COMPUTER SIMULATIONS USED FOR ENGINEERING DESIGN

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INTRODUCTION

The modern computer gives the design engineer almost unlimited capability to process data. This resource used on the accurate analytical models of various compressor phenomena now available in the literature gives the engineer a powerful tool - the computer simulation. The tool is enhanced markedly if the approach is taken that a simulation is a source of quantitive information for the engineer rather than a prediction of a phenomenon alone.

The ultimate goal of a design engineer is to develop a successful product. Large amounts of information are needed. The modeling of phenomena is only one step toward the goal. Thus, to develop a successful simulation, one must examine the engineer's purpose in using the simulation.

PURPOSE OF A SIMULATION

The prime purpose of a computer simulation is to provide information that the engineer may use in performing his job. The design engineer enhances a current design or develops a new compressor design - the computer simulation is a tool that gives the engineer the means of obtaining quantitative information that he may use throughout the course of his job. Thus, in order for a simulation to fulfill its purpose, consideration must be made for the situations that a design engineer faces.

The classical picture drawn of an engineer is one who combines his experience, analytical capabilities and creative genius and solves almost any problem assigned. If the analysis used is sufficiently complex or requires repeating, then a computer program may be warranted. The engineer then develops a program which reads the necessary input values, directs the computer to perform a certain set of instructions, and the values sought are read out. Such a program, although successfully meeting a current need, has very limited value when other areas of responsibility and future needs of the engineer are considered.

One of the most perplexing assignments for a design engineer is that of defining a problem. For example, a bearing failure rate is too high in a certain design. The bearing for this compressor was designed using information obtained from several analysis programs or a bearing simulation - a larger program including the above mentioned analysis programs plus the necessary logic to integrate the programs into a simulation. But why is the bearing failing? Was the analysis incorrect? Were the assumptions made while designing the bearing valid? Is there an unknown variable? Is the application more severe than anticipated? Is the bearing hardness or finish or the lubricant not meeting specifications? Etc.

A computer simulation specifically for the design of a bearing or lubrication system can not answer very many, if any, of the questions confronting this engineer unless the simulation was developed with the prime objective of providing information and not just yielding a certain size bearing, lubricant viscosity, clearance, etc. for a specific application. Suppose bearing end leakage flow rate information were available from the bearing simulation and the bearing friction loss information were available from a thermodynamic compressor simulation. Then, the engineer could establish if bearing temperature rise is a problem. Suppose the bearing pressure distribution were available. Then, a misplaced oil groove could be more easily spotted. A simulation by the information it can provide can be a valuable tool in defining problems.

The simulation can provide sensitivity information. Is the value of a certain dimension in a high gradient region such that the performance of the production compressors vary excessively? Or should a production run of a particular compressor part not meeting a certain dimensional tolerance be scrapped or can they be used on a different application without adversely affecting performance? A performance simulation with geometry subroutines that accept dimensions taken directly from production blueprints can provide considerable information to help the engineer answer these types of questions. Also, such a simulation would be used as long as the compressor is produced.

Occasionally the engineer encounters the problem of alterning the performance of a compressor to meet the needs of a new application. Which compressor chassis? What design variables can most efficiently meet the objective? Awareness of this situation during the development of a simulation can increase its potential significantly. This situation is arising more frequently as consumer demand is changing at a more rapid pace than ever before.

The situations cited above involve the analysis of an established design. For a new design or simplification of an existing design, synthesis is necessary. Synthesis is the combining of certain basic elements into a complete functional compressor. This is a real challenge since the simulation must have a high degree of generality and also include the capability to anticipate future changes. Consider the flow path illustrated in Fig. 1 as an example. The path may be a series of five tube segments assembled to conform to this geometry - two 90° bends and three straight sections. Fig. 2 is the same geometrically as Fig. 1 except that the variables shown assume different values. The three straight segments have been eliminated by setting their lengths to zero and changing R1 and R2. It is a different assembly but the computer program is the same for both.

There is an immediate spin-off from this effort. In generalizing the geometry to anticipate the variables that may be studied with the completed simulation, the design is being scrutinized in a unique fashion. The assembly in Fig. 2 may not have been considered before.

The above sampling of situations encountered by design engineers indicates the need for careful planning of a simulation. The simulation should meet several criteria in order to be used to its fullest potential.

SEVERAL CRITERIA FOR SIMULATION DEVELOPMENT

1. Establish what information a designer feels he needs from a simulation. Some of the needs may not be met practically by a simulation but consideration should be given to them.

2. Provide a means of optionally outputting the desired information. For example, a thermodynamic simulation may always output the energy requirements, losses and performance characteristics of a certain compressor. If the designer desires cylinder pressures, he may request it by setting a flag to a certain value; i.e. if FLAG
   = 0   he obtains standard output,
   = 1   he obtains cylinder pressure,
   = 2   he obtains gas velocity in the port,
etc. where FLAG is an input variable.

3. The basic system being simulated should be set up in a general form. This approach permits establishing flow areas, head clearances, length to diameter ratios, compressor frame or family size, etc. This form is used primarily in the early stages of a new design.

4. The basic simulation can be mated to special geometry subroutines that yield the specific dimensions. These routines can provide information also to tooling engineers and layout draftsmen. This advanced form would be used in the final stages of design and to support pilot and production runs.

5. The simulation should be documented. This enables future updating of the simulation and correction of errors with a minimum of effort. Also, documentation reduces misuse or misunderstanding of the results. For example, consider two elements of a compressor moving relative to each other. Assume that there are two phenomena influencing the compressor efficiency. As the clearance between the elements increases the increased leakage reduces efficiency while the reduced friction would specifically increase efficiency as shown in Fig. 3. If the simulation does not model the leakage, then an unknowing engineer would draw the false conclusion that the wider the clearance the more efficient the compressor. An experienced engineer could conclude that the simulation is not valid.

CONCLUSIONS

Accurate simulation of many of the phenomena encountered in compressors is now possible. The numerical processing capability necessary for the design engineer to use these models is readily available with the modern computer. But for the engineer to utilize these resources to the fullest extent, the simulation should not be developed with the only goal of modeling a phenomena accurately. It should be regarded as a means of generating quantitative information for use throughout the design process. The information a design engineer needs depends on whether he is designing, or trouble shooting a compressor. During the early stages of the design process, a general form of simulation is needed in order to discover and study various dimensionless ratios, critical parameters and limitations. As the design progresses, specific geometry outines are added to finalize the design and to provide needed information for pilot and production runs. During the final stages of development and during production, this specific form of the simulation provides considerable information for defining sudden and unexpected problems. A good simulation will provide information to meet many of the diverse and unexpected needs of a design engineer.

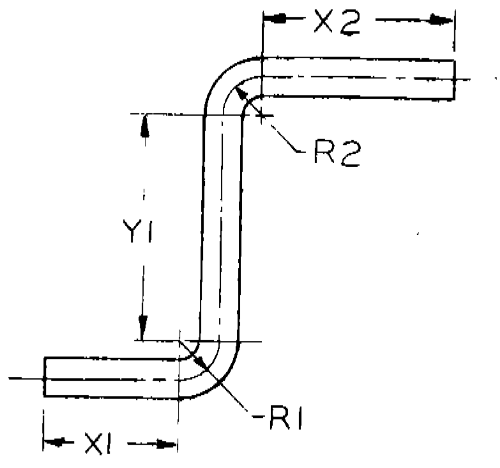

FIG. 1

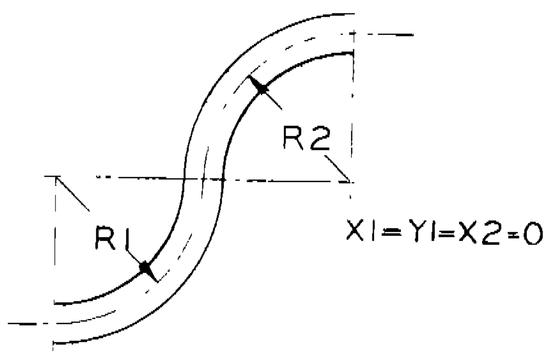

FIG. 2

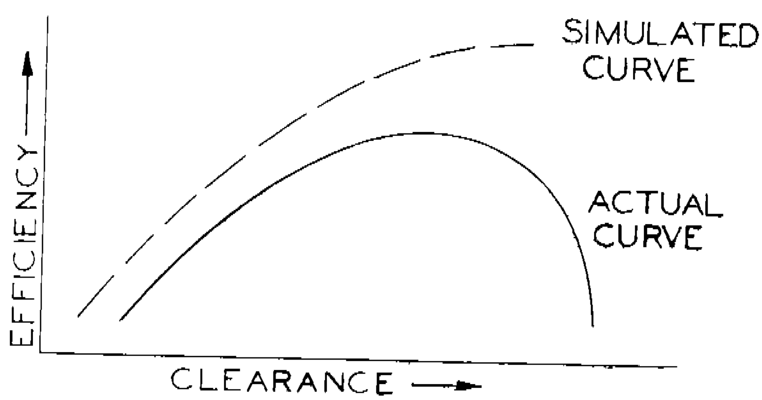

FIG. 3